A TRANSISTORIZED CHROMATRON COLOR TELEVISION RECEIVER

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SUMMARY

This paper presents the circuits and system aspects associated with the design of an all-transistor color television set using the Chromatron color tube. It is intended to be read with a previous paper[6] describing the color-processing circuitry, and the two papers together form a complete description of the set design. This paper, in particular, is concerned with the problems associated with the generation and regulation of high voltage, and with obtaining proper color video response using semiconductors. Other aspects of the design are presented for the sake of describing a complete schematic.

INTRODUCTION

Recent sales of color television have shown a very rapid increase. If the color trends follow those set by black and white, then one could predict that transistorization and small screens will begin to take a large share of the market. Transistorization should come about much more quickly than it did with black and white for several reasons: the proper semiconductors are readily available at the right price, new designs can begin immediately with semiconductors, and much black and white experience can be carried over into the color field. For these reasons Fairchild was vitally interested in investigating the problems encountered in transistor color-set design.

It appeared at the outset that a transistor color television should be reasonably small to better demonstrate the advantages of using semiconductors. At the time the program was started the only small color television tube available was the Chromatron manufactured in sample quantities by the Chromatic Laboratories of Paramount Pictures Corporation. An additional incentive to the choice was the information that such a tube or variations of it was being manufactured in Japan. Since then several American manufacturers appear to be using the shadow mask tube in sizes down to 15 inches and that small screen color sets manufactured in this country will likely use this tube. In addition, Fairchild had already investigated some of the shadow mask color processing problems with the thoughts that a hybrid set would be the first step towards all-transistor color television.

Although the choice of the Chromatron tube was set primarily by the availability of a suitable tube, there were also more general considerations:

1. Except for the color-processing circuits, most of the system problems were common to both the Chromatron and shadow mask tubes.

2. For the same amount of beam current, the Chromatron gives a brighter picture than the shadow mask and hence simplified the high-voltage problems.

A photograph of the completed set is shown in Fig. 1. It was finished in the spring of 1965 and first exhibited at the Chicago Spring Conference on Broadcast and Television Receivers. The color processing circuitry has already been described at that conference and is published in the IRE Transactions on Broadcast and Television Receivers.[6]

FIG. 1a

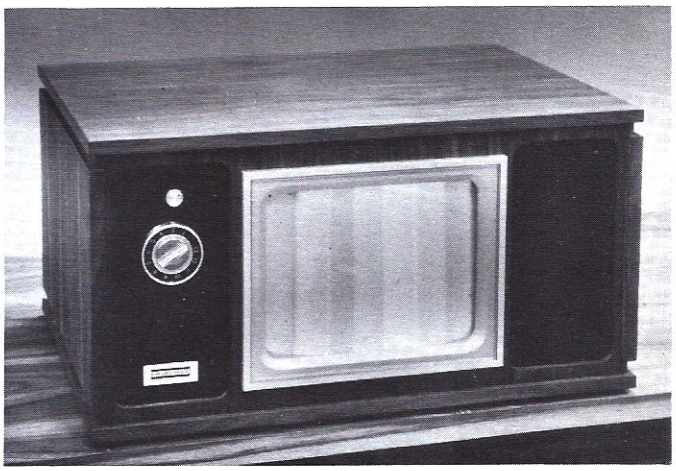

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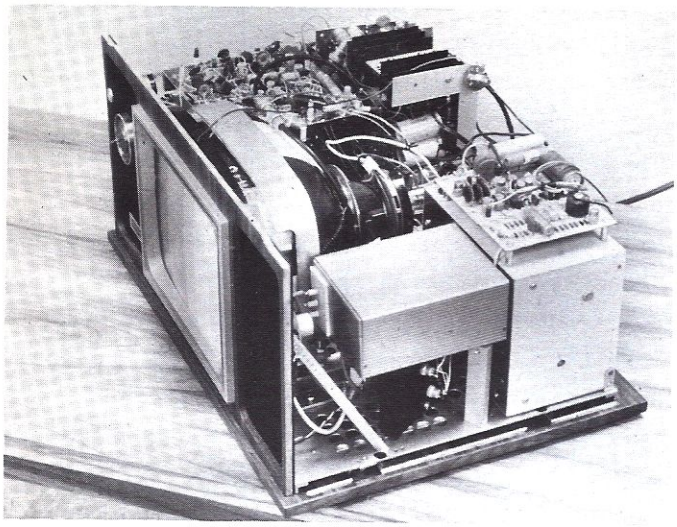
FIG. 1b



THE SET

A block diagram of the receiver is shown in Fig. 2.

Certain parts of the receiver are common to conventional circuitry in black and white sets and some will be discussed only briefly. These are: The Audio, Audio I-f, Vertical Deflection, Power Supply, Horizontal Phase Control, and Oscillator. Of particular interest, are the Tube and its biases, the Horizontal Output, High-voltage Regulator, the Tuner and the Video I-f.

The Picture Tube[1,2]

The C 6003 Chromatron picture tube made by the Chromatic Division of the Paramount Pictures Corporation is illustrated in Fig. 3. The phosphors are deposited on the faceplate in vertical stripes—in a "majority red" or red-green-red-blue-red sequence. There are 168 five-mil stripes per inch across the face of the tube. Correct color selection is obtained by the use of a grid of alternately polarized vertical wires located about 1/4 inch behind the phosphors. In the case of the tube described here, the grid wires were made part of the tuned circuit which was driven at the 3.58 color subcarrier frequency by about 10 watts at 150 volts rms power. Color selection was obtained in one of two ways: Either by synchronously gating the luminance signal or by simulating the gated luminance signal with a harmonic series. For obvious reasons the first technique is called the "chroma gate" system and the second technique is called the "1-2-4 system."[3]

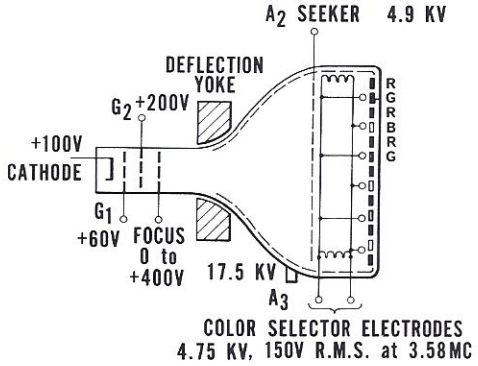


FIG. 3 THE CHROMATRON PICTURE TUBE

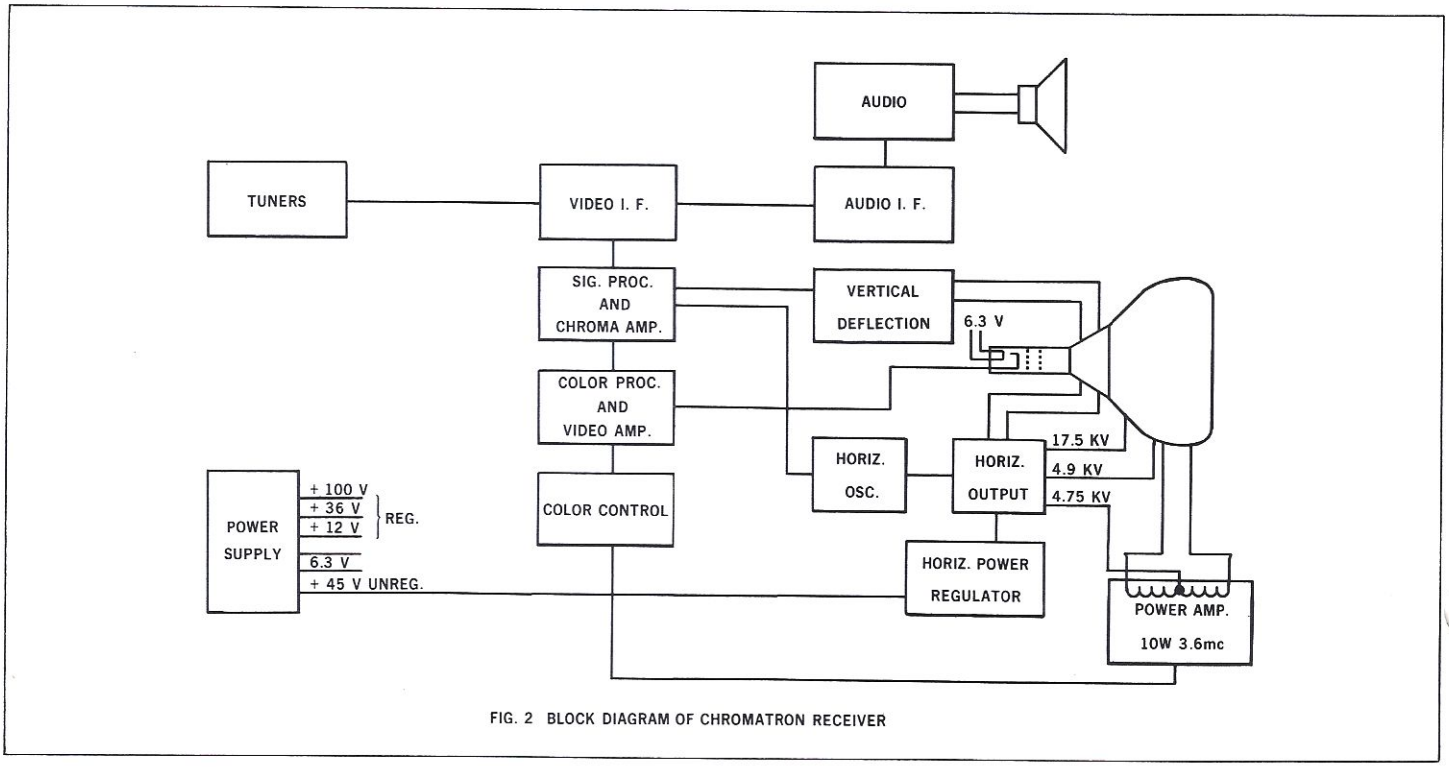


FIG. 2 BLOCK DIAGRAM OF CHROMATRON RECEIVER

The biases applied to the tube are: 17.5 kV of final anode voltage, 4.9 kV "seeker" voltage, 4.75 kV switching grid voltage, 0-400 V focus voltage, 200 V at G_2, and cathode and G_1 voltages as required. All of these voltages must be accurately regulated as in the shadow mask tube.

The High-Voltage Section

Figure 4 shows the horizontal output transformer, high-voltage rectifiers, and control circuitry used to drive the Chromatron picture tube. In addition to the 17.5 kV acceleration voltage, 4.9 kV seeker electrode and 4.75 kV switching grid voltages are provided. The difference voltage between the seeker and switching grid is varied as beam current changes in order to maintain color purity; and a feedback loop from the resistor-divider network on the 4.75 kV supply, controls a regulator supplying voltage to the horizontal output stage to help maintain constant high voltage.

A diagram of the regulator used to control the primary power to the high-voltage circuit is shown in Fig. 5. This is a conventional series type regulator except that the controlling

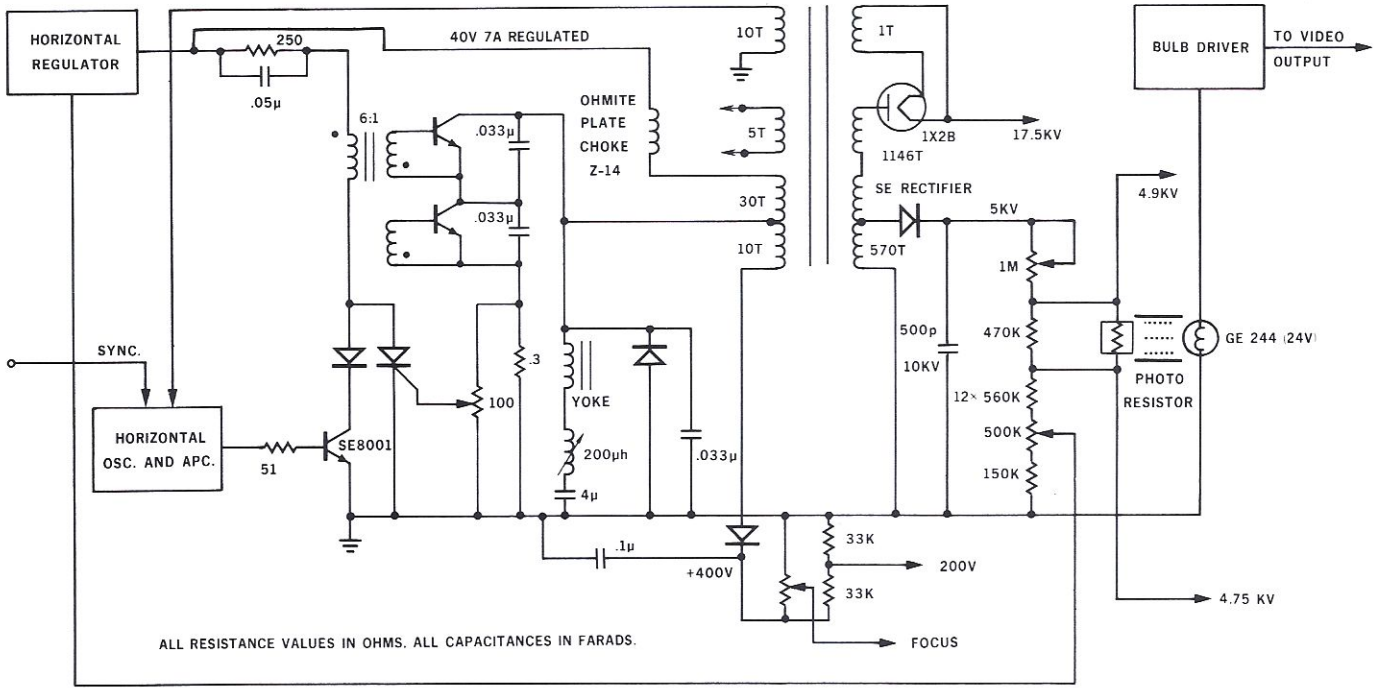


FIG. 4 HORIZONTAL OUTPUT AND HIGH VOLTAGE CIRCUITRY

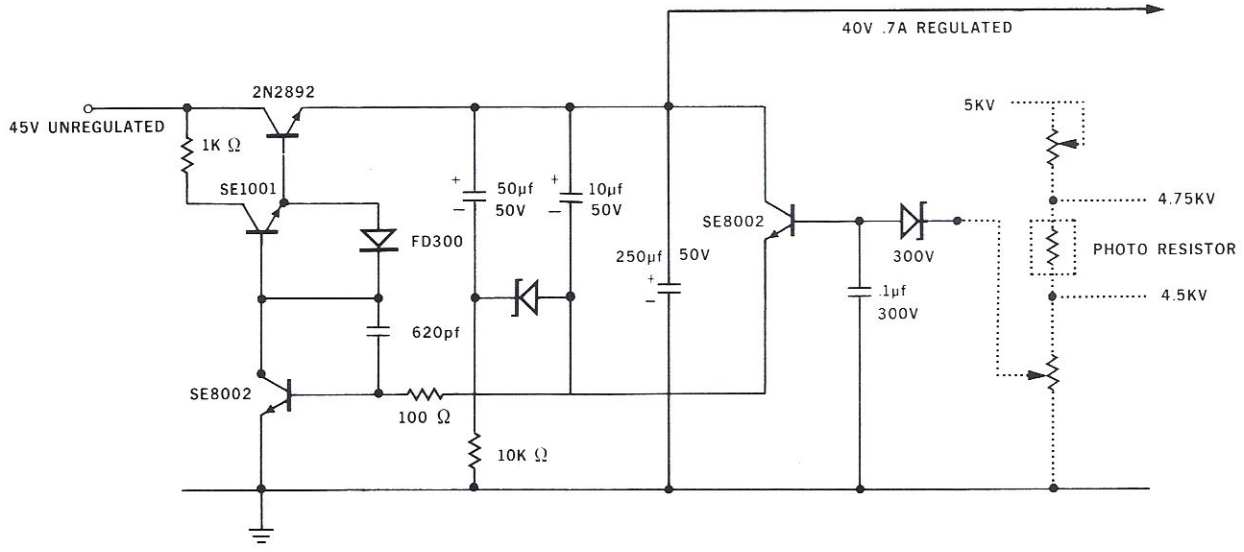


FIG. 5 REGULATOR FOR HORIZONTAL OUTPUT

signal is obtained on a divider from the 5.5 kV winding of the transformer. While the control of high-voltage primary power provides a good measure of secondary output control up to the maximum beam current of 400 μA, it was still found necessary to apply a slight secondary correction to the switching-grid bias voltage for best overall color response. This was a subjective relationship obtained by plotting, under operating conditions, the relationship between beam current and seeker minus switching grid voltage for the best color purity as shown in Fig. 6.

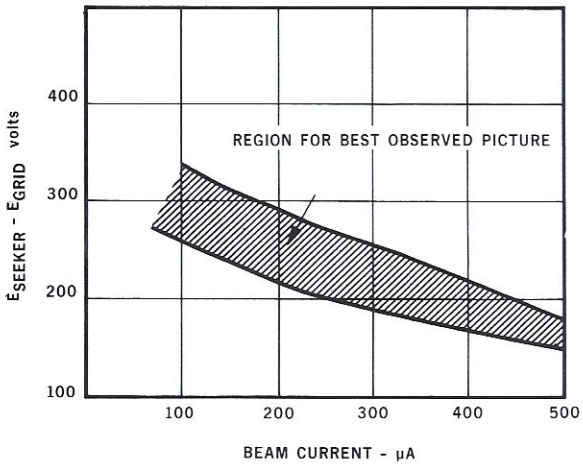


FIG.6 EFFECTS OF SEEKER TO GRID VOLTAGE

A control circuit consisting of a photoresistor controlled by a light bulb is used to vary the resistance in the divider network between the seeker and switching grid tap points. A plot of the transfer characteristics of the photoresistor control circuit is shown in Fig. 7.

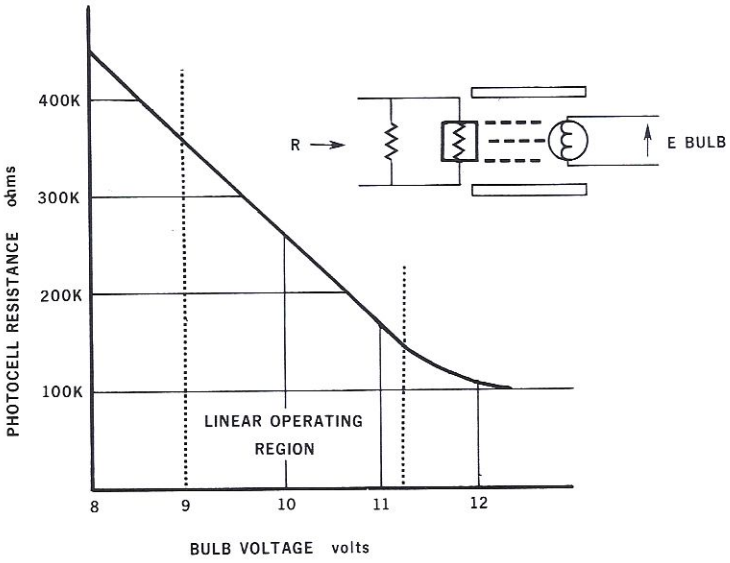


FIG. 7 BULB PHOTOCELL TRANSFER CHARACTERISTICS

Since the divider network acts as a current source of approximately $\frac{4.7\,kV}{8.8\,M\Omega} = 0.53$ mA, the seeker minus grid voltage will vary

$$\Delta E = I\Delta R$$

$$\frac{\Delta E}{\Delta R} = 0.53 \times 10^{-3} \text{ Volts/Ohm}$$

or 53.0 Volts/100 K

Mating the photoresistor control circuit to the seeker and grid divider network resulted in a transfer function shown in Fig. 8.

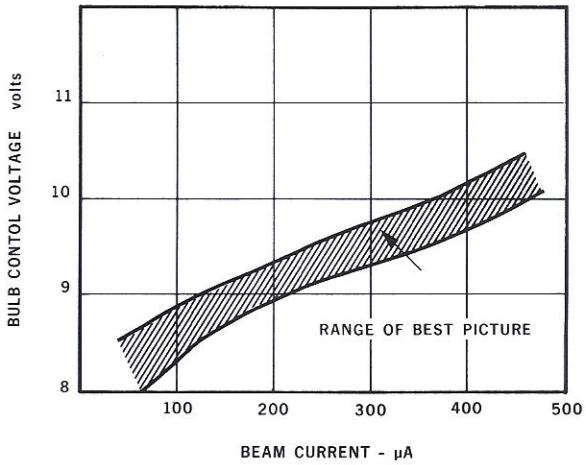


FIG. 8 BULB VOLTAGE FOR BEST PICTURE AT DIFFERENT BEAM CURRENTS

The circuit shown in Fig. 9 is used to vary the bulb voltage in accordance with beam current. Both level and gain controls are provided to insure proper characteristics when changing picture tubes, aging, etc.

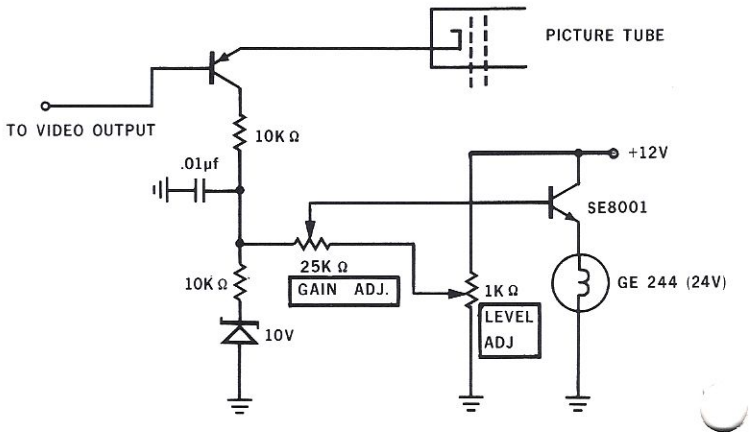


FIG 9 BULB DRIVER CIRCUIT

Several considerations lead to the protection of the horizontal output stage:

The regulator feeding the horizontal output stage provides 40 volts at 0.7 ampere of power. There is a horizontal driver-clamping circuit that provides protection for the horizontal output transistor against high-voltage short circuits. This clamping is done with a silicon controlled rectifier which responds to excessive peak current in the output stage.

The real power drawn from the high-voltage supply is 7 watts average, while the reactive energy stored is approximately 1 millijoule or 20 watts per cycle. This presents a fairly small ratio of stored-to-dissipated energy, resulting in a large unbalance of transformer current. In order to ensure against saturation of the horizontal output transformer core, and hence horizontal output device destruction, it was necessary to use a comparatively large air gap of 8 mils. This also resulted in smaller primary inductance, therefore, larger circulating current and more stored energy in the system.

The Vertical Deflection Circuit[7]

Figure 10 shows the complete vertical deflection circuit. This circuit employs four transistors in a unique multivibrator circuit in which the multivibrator is essentially separated from the influences of the horizontal information in the yoke. The basic multivibrator is formed by transistors Q_1 and Q_2; and during the flyback period, transistor Q_3 is saturated in the common-base mode. Q_2 performs the dual function of discharging the sweep generating capacitors C_4 and C_5 through the emitter-base diode of Q_3 and of clamping the base of the output transistor Q_4 to ground. This latter action allows the flyback voltage across Q_4 to rise to the BV_{CES} rating and completely eliminates the dissipation of flyback power in the transistor. To control the height of the flyback pulse, condenser C_7 resonates with the yoke and choke inductances while the current flowing through it is used to control the base clamping action on the output transistor.

The Tuner

The tuner used for the set was a conventional commercial transistorized tuner using three silicon planar transistors. No special precautions or alignments were used to achieve adequate sensitivity and color response.

The Video I-f Amplifier

A diagram of the video i-f amplifier is shown in Fig. 11. This three-stage circuit has 80 db of voltage gain and 60 db of forward AGC. The gain control is achieved in the first stage, the device being an SE 5023. The second stage uses an SE 5024 and the third stage an S 1763. The latter device is similar to an SE 5025 which was designed specifically for the video i-f output application, but employs a metal TO-5 package for higher dissipation. The output stage supplies a nominal 3 volts of video with the capability of 6 volts of linear output for overload capability. The first two stages are operated unneutralized while the third stage is neutralized to provide a high-output impedance.

The overall response obtained is similar to the conventional

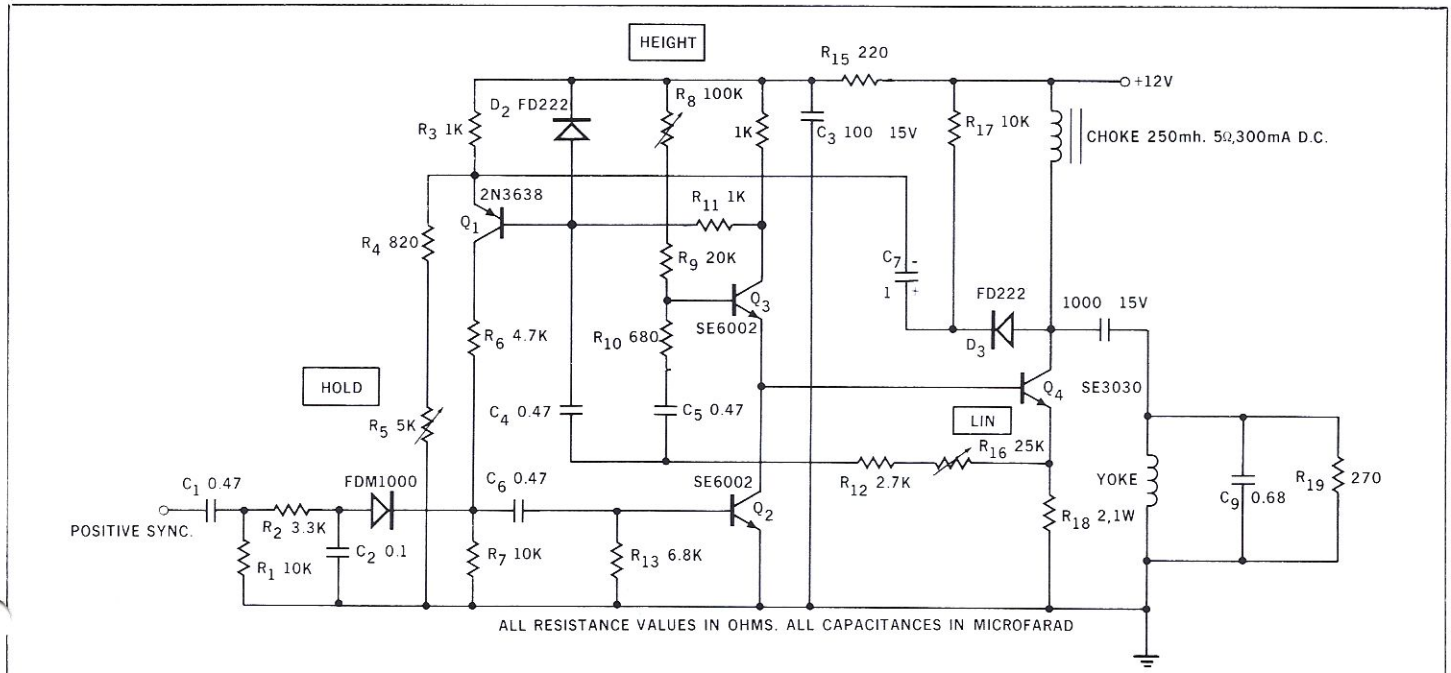


FIG. 10 COMPLETE VERTICAL DEFLECTION CIRCUIT

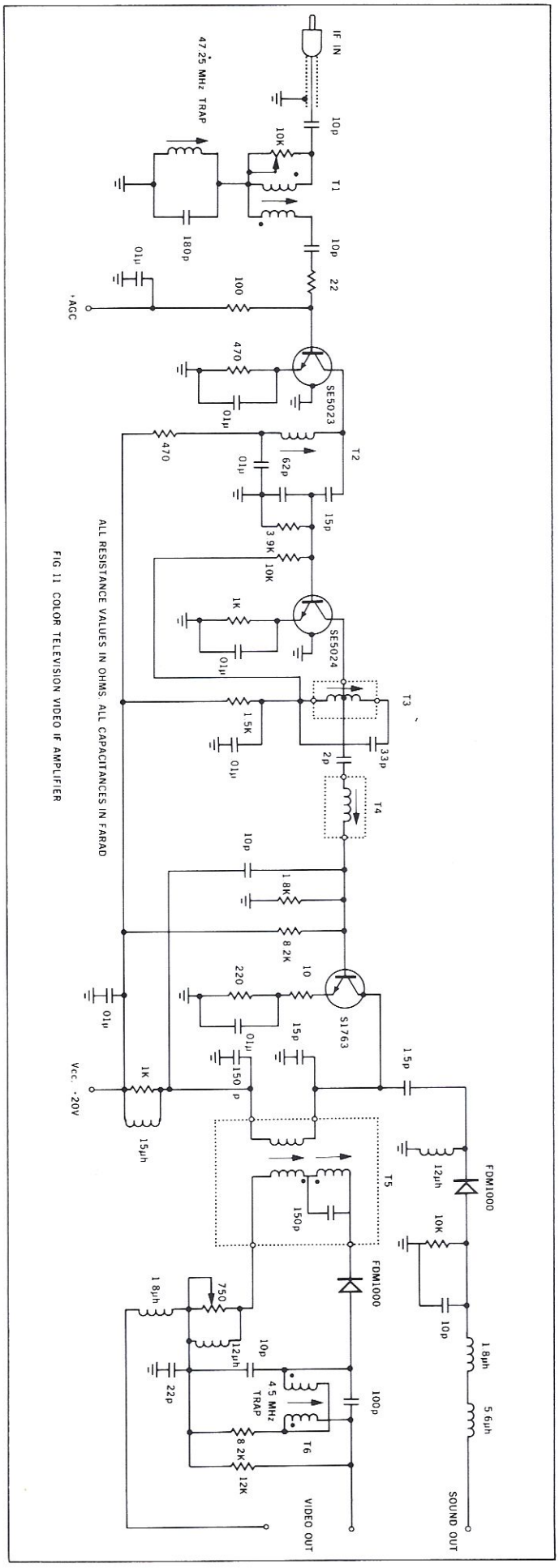


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FIG 11 COLOR TELEVISION VIDEO IF AMPLIFIER

bandpass now used by most color manufacturers, where the chroma information lies on the slope of the response. This response is formed by the input bifilar trap, a relatively broad first interstage, a double-tuned second interstage, and the output transformer.

The input bifilar-T trap attenuates the adjacent sound carrier.

The sound detector is capacity coupled to the primary of the output transformer. After the sound has been taken off, a 41.25 MHz trap in the output transformer prior to detection and a post detection 4.5 MHz bifilar-T trap removes it in the Video Channel. The use of the bifilar-T traps confines the phase distortion to the immediate vicinity of the trapping frequency.[4,5] (For further description of the i-f amplifier see Refs. 8 and 9).

PERFORMANCE OF THE SET

The performance of the set was judged to be quite good. The claim made by the proponents of the tube that good color is best achieved with high-brightness levels certainly appears to be true.

SET UP

Setting up the Chromatron is extremely easy since the usual convergence and correction controls are not required for a single-gun tube. Apart from the color processing circuitry, the set-up consists of adjusting the yoke position, setting the high-voltage regulation controls and the twist coil current. All of these set-up functions could be performed without the need for a color generator or a color program.

CONCLUSION

External magnetic fields do have an influence on the color quality giving an effect similar to poor convergence in the normal shadow mask set but appearing as a red-blush. Care had to be taken in the construction of the chassis to keep ferrous material away from the vicinity of the faceplate, but otherwise no precautions were found to be necessary.

One anticipated electrical problem concerns radiation from the 3.58 Mc oscillator and power amplifier. Some mechanical and electrical precautions were taken to guard against this and little trouble was encountered. Radiation energy readings were not taken, but it was found that adjacent color sets were not affected when the chromatron was operating. There is no doubt that much of the radiation attenuation was due to the construction of the tube whereby the resonating coils were placed inside the envelope immediately adjacent to the switching grid. This technique eliminated to a large extent the external radiation due to the high circulating currents in the resonant loop.

As described in the previous chromatron paper,[6] two systems of color processing were evaluated. The chroma-gate system did not give as good a color picture as the 1-2-4 system since the color response was critically dependent on having very high-speed pulse response. It was felt that the chroma-gate system could have been improved but the necessary work was not completed. The problem with the 1-2-4 system is the extreme difficulty in aligning the many systems of demodulators and modulators. However, the ease of obtaining the color bandwidth more than compensated for the alignment difficulty.

The set used 70 watts of power and contained 66 silicon transistors as follows:

VHF Tuner	3
UHF Tuner	1
Video I-f Amplifier	3
Audio I-f Amplifier	2
Audio Amplifier	4
Sync Separator & AGC Circuit	7
Color Processing Circuit	18
Color APC Circuit	6
Horizontal Deflection Circuit and its Regulator	9
18 V Regulator	3
36 V Regulator	3
Vertical Deflection Circuit	4
Switching Grid Power Amplifier	3
	66

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